THE VISUAL EVOKED CORTICAL RESPONSE AS A MEASURE OF STRESS IN NAVAL ENVIRONMENTS: METHODOLOGY AND ANALYSIS
(1) Slow Flash Rates

by

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SUMMARY PAGE

PROBLEM

To evolve techniques for assessing differences among visual evoked responses (VER) from the human cortex, recorded under different environmental conditions.

FINDINGS

Two techniques have proved successful; one of these will evaluate statistically subtle differences in evoked responses, while the other reveals fundamental underlying processes.

APPLICATION

The visual evoked response is a promising tool in evaluating responses of men to typical Naval problems such as the hyperbaric or narcotic conditions imposed on the diver. These analytic techniques allow use of the VER in solutions to these problems.

ADMINISTRATIVE INFORMATION

The investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit MR005.01.01-0130BOLL A Visual Test of Fatigue and Physiological Disturbances in Navy Divers and Submariners. The present report is No. 1 on that Work Unit. It was approved for publication on 25 June 1971 and designated as Submarine Medical Research Laboratory Report No. 669.

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ABSTRACT

The emphasis in this report is upon methodology for use in evaluating the visual evoked response (VER), since our primary interest is in using it as a tool in the study of Naval problems. In order to employ the VER to full advantage, techniques have to be evolved to assess the significance of differences among evoked responses; two such methods are assessed in this paper. One of these, a determination of a mean VER, is effective in evaluating the statistical significance of subtle differences among evoked responses. The second technique is designed to isolate differences in underlying processes in the VER by summating responses to one stimulus and subtracting the same number of responses to another. In the course of these investigations, we have found an element in the VER strongly responsive to patterned stimuli and small differences among VER's attributable to hue. The latter are in excellent agreement with psychophysical data on the color response of normal and color defective subjects.

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INTRODUCTION

The visual evoked response (VER) has received widespread use and publicity in the last ten years as a promising new tool for studying human cortical functioning. The VER is a component, elicited by a visual stimulus, of the human electroencephalogram; it is recorded from scalp electrodes placed over the primary visual projection area of the occipital cortex. The commercial availability of small, special-purpose computers, designed specifically to extract these stimulus-evoked responses from the EEG, has been the major impetus for its increased use. While stimuli to any sense can be used to elicit an evoked response, the use of visual stimuli has been most common due to the fact that much of the visual projection area is located on the surface of the cortex and is easily accessible to scalp electrodes.

A major reason for the widespread interest in the VER's is that they hold promise for objective measurements of perceptual phenomena which are otherwise largely subjective. Thus it has been suggested that refractive error, color vision, size of visual field, scotoma, and acuity could be quantitatively assessed with the VER. This would eliminate the need for highly skilled medical examiners for routine testing, and of special devices to detect malingerers.

Moreover, the possibility of assessing brain functioning directly and quantitatively is most attractive: it could afford a direct measure of the physiological state of an individual without interfering with his activities. It could be used to assess fatigue, stress, attentiveness, or even general intelligence, providing an indication completely independent of what the man might say.

With these goals in view, the extensive research in the area is certainly understandable. Unfortunately, there are numerous difficult problems that must be first resolved. These stem from the complexity of the VER itself, the vast number of variables that can affect it, the variability associated with its measurement, and a lack of knowledge of its underlying physiology.

The VER is a complex waveform comprised of negative and positive components that extend for several hundred milliseconds after the stimulus. The number of variables which may affect it is enormous; excellent summaries of the variables have been given by Perry and Childers[1] and in several other reviews.[2] They can be generally classified into stimulus variables and response variables. Thus, under stimulus parameters, the waveform may be affected by the size, color, pattern, or retinal location of the visual target. Similarly differences in waveform might be related to the subject's attitude or motivation,

whether the stimulus was meaningful to him or relevant to his task at the moment.

Since there is a certain amount of variability under the same conditions, the investigator's first problem is to decide whether a given change in waveform is real. If the experiment is repeated, how likely is it that the same difference will be found? Thus, some statistical assessment of the significance of the difference must be made. If difference is reliable, the next question to be raised concerns its meaning. Suggestions have been made as to the basis of some of the components. For example, Harter and White[3] suggest components at 100 and 180 msec are related to contour processes; Andreassi[4] believes he has found the physiological correlate of "one" vs "two" response; and Gastaut[5] finds components related to dark adaptation. Also several investigators[6] have implicated the late components, at 300 msec or more after stimulation, with decision processes. Nonetheless, there is no comprehensive theory of the underlying mechanisms, and it is up to each investigator to relate the observed changes in waveform to specific stimulus or response variables.

The possibility of experimental artifact is always great; for example, other neural mechanisms (such as auditory or muscular responses) may be time-locked to the stimulus. These problems have been discussed and solutions suggested by several authors.[7]

More subtle differences may occur simply as a function of time. Uttal[8] gives an example of 10 evoked responses determined during the course of an hour under the same experimental conditions. Progressive and systematic changes occurred which might well have been attributed to a stimulus variable had it been ordered sequentially. The phenomenon is probably related to habituation which has been extensively investigated.[9] Obviously controls for such serial effects must be provided in the experimental design.

Considering these vast problems it is understandable that many of the results obtained with the VER are controversial; that many effects found by one investigator cannot be replicated by another; and that conflicting claims of the meaning of the various components are prevalent. Since we are using the VER as a research tool to investigate problems arising in submarines and diving, we had to evolve methods to circumvent these problems. This paper reports on several techniques we have found to be successful and presents illustrative data from each of them.

First, data are reported which speak to the question of individual differences, both among different subjects and within the same subjects over time.

Second, the effect of two stimulus differences are presented to illustrate the size of differences found in the VER. One of these, a comparison between a blank field and a highly patterned field was chosen as an example of a large effect; there is universal agreement among investigators that degree of patterning is an important stimulus variable.[10] The second, differences in the color of the stimulus, yields a much more subtle difference and one that is quite controversial.[11]

Third, data have been accumulated using an experimental technique advocated by Carroll White[12] for testing hypotheses concerning the underlying processes of the VER. This technique isolates the contribution of various underlying mechanisms to the VER by summating responses to one stimulus and subsequently subtracting the same number of responses to a stimulus which differs from the first in that one feature has been omitted. Its usefulness in extracting subtle differences can be tested by specific predictions.

APPARATUS AND PROCEDURE

The VER's were recorded from bipolar electrodes located on the midline of the scalp 2 cm and 7 cm above the inion. A ground electrode was placed on the subject's ear. The potential from the electrodes was fed to a Grass P511 Pre-Amplifier which was set to amplify the signal at a nominal value of 100,000. The signal from the preamplifier was led both to a Tektronix oscilloscope, for on-line visual monitoring, and to a Technical Measurement Corporation's Computer of Average Transients (C.A.T.) for summation. A pre-set sweep counter by TMC regulated the number of signals summated by the C.A.T.

A number of different visual stimuli were used. These consisted of blank fields of color (red, green, blue, or gray) or of vertical stripes of one of the same colors and white. All were 11 inches square and subtended a visual angle of 12° on a side at the viewing distance of 4 ft, 3 inches; the stripes subtended an angle of 30 minutes.

The visual targets were constructed of colored papers; their spectral reflectances were measured in a General Electric Spectrophotometer and CIE chromaticity coordinates calculated from the spectral distributions. These values are given in Table I. Spectral energy distributions of the actual Photostimulator source was used in these calculations; the result is very similar to the use of Illuminant C. Note that, while the reflectances of the blue, red, and gray are the same, the green reflects twice as much light. However, there is no evidence in the literature of differences in VER's as a result of intensity differences of this magnitude,[15] nor could we find any difference by reducing the intensity of the Photostimulator to compensate for the greater green reflectance.

Table I. Specification of the Colored Targets.*

Colored Targets	CIE Chromaticity Coordinates			Reflectance
	x	y	z	
Red	.558	.361	.081	.21
Green	.358	.484	.158	.46
Blue	.246	.293	.461	.22
Gray	.303	.322	.374	.20

*Tables II thru IX will be found at the end of the Report.

The targets were illuminated by a Grass PS-2 Photostimulator which was positioned over the subject's head. The duration of individual Photostimulator flashes is about 10 μsec; the flash rate was one per second.

The highest intensity on the Grass Photostimulator, 16, was employed. This resulted in a luminance of 0.5 ft-L reflected from the gray, red, and blue targets, about 1.0 ft-L from the green, and 2.0 ft-L from the white portions of the striped targets as measured by a visual match to a standard using a Luckiesh-Taylor brightness photometer.

The timing mechanism in the C.A.T. was used to drive the Photostimulator. The analysis interval—that is the length of interval of EEG which is summated by the C.A.T.—was also one second. Two hundred repetitions of the one second interval were added for each VER.

For the recording of the VER's, subjects were seated in a shielded room and instructed simply to look at the target near its center. The room lights were extinguished for the actual recording and turned on during an approximately 2-minute break between records.

The order of presentation of targets was always counterbalanced within a single session. For example, in one session, the VER's for blank and striped fields of blue might be compared; one order of presentation of the visual stimuli would therefore be: blue blank; blue and white stripe; blue and white stripe repeated; and blue blank.

Subjects were five members of the permanent staff of the laboratory who were thus available for repeated testing over extensive time periods.

RESULTS

Blank Fields of Color

Visual evoked responses of one subject to the same stimulus, the gray field, were recorded on five separate occasions over a two-month period. These five records have been superimposed in Fig. 1 to illustrate typical differences among recordings. While the overall pattern remains the same, there are differences in both amplitude and latency of the various components. In order to assess these differences, measures were made of latencies and amplitudes of each major component for each record, and means and standard deviations calculated. The top record of Fig. 2 shows

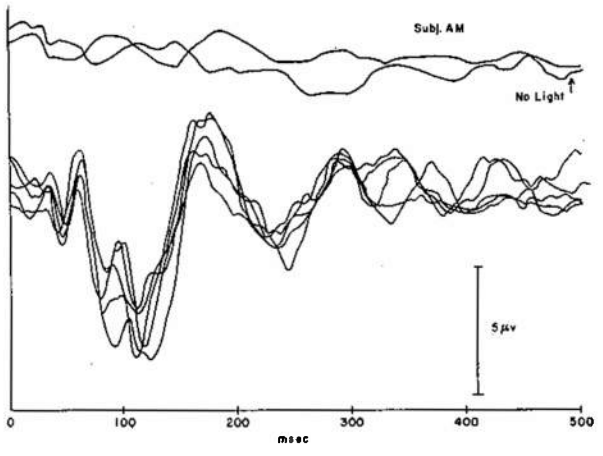

Fig. 1. Five VER's recorded from the same stimulus, a neutral gray of 1.0 mL, over a two month time period for one subject. Two control VER's--200 repetitions of the 1 second EEG with no light stimulus--are shown at the top.

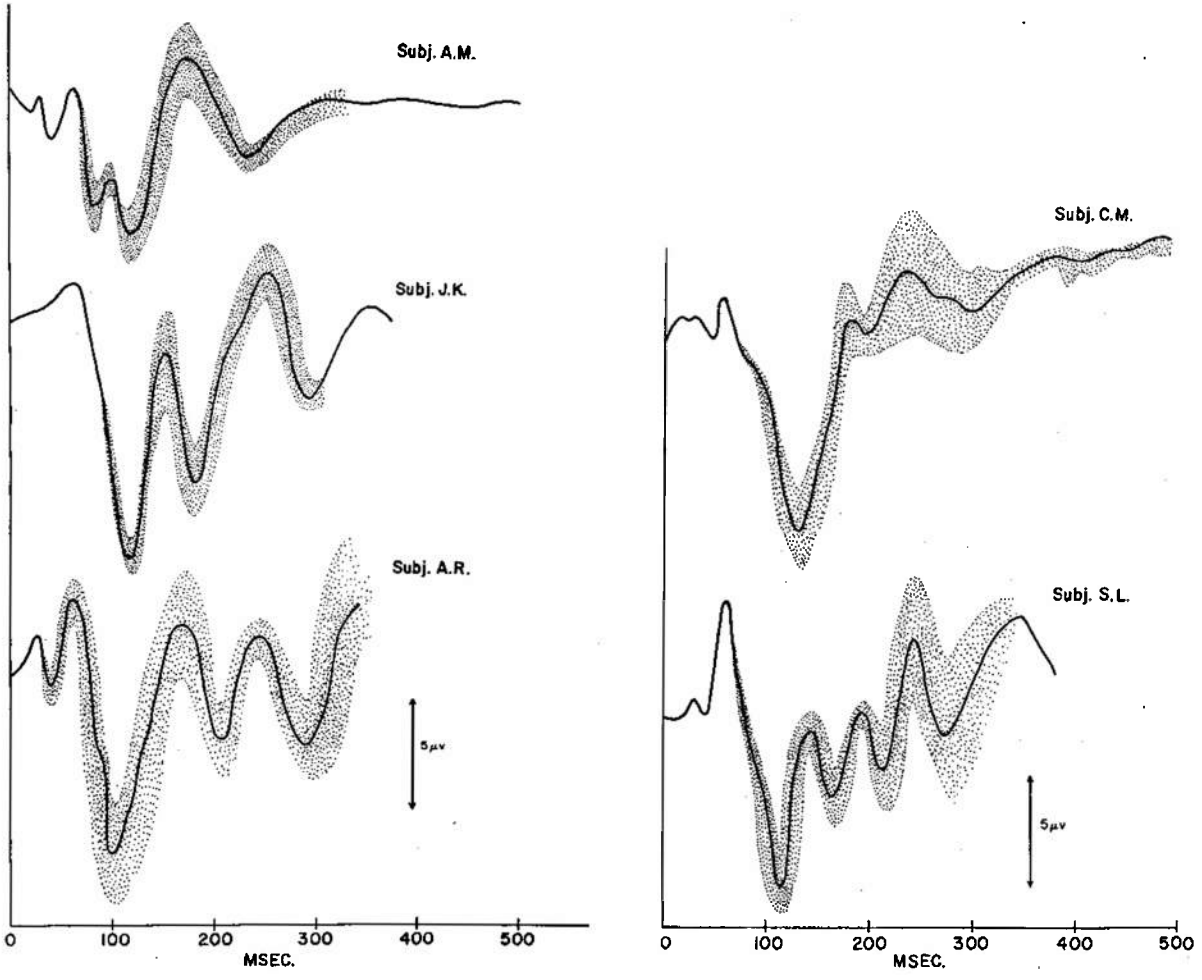

Fig. 2. Mean VER's for five subjects in response to a blank gray field. The amplitudes and latencies were averaged and ± one standard deviation of these values are indicated by the shaded areas.

the mean curve for the same data together with the shaded area which depicts one standard deviation on either side of the means.*

Comparable mean responses plus or minus one standard deviation are also shown for four other subjects in Fig. 2; the data are given in Table II in the Appendix. Some features are consistent among individuals; for example, a positive inflection around 60 msec, a large negative one around 100, with at

**The arbitrary decision was made to superimpose the curves at the first major peak, since this was the first consistent point for many records. This results in a loss of information about the variability of amplitude about this point.*

least one large positive** variation thereafter. The differences among individuals, however, are so sizeable that it would be difficult to find even the same number of prominent components to measure, much less to assess which were comparable. For example, between 100 and 200 msec, SL has two prominent positive inflections; three subjects display only one, but a very large one; and the fifth subject has only a minor shoulder during the same time period.

For all subjects, differences in the latency of components from one record to another were small; on the other hand sizeable variations in the amplitude of components were typical of all subjects.

Figure 3 shows an overlay of five VER's obtained for one subject in response to a plain field of red or of green. Variability among days, particularly in the amplitude of the components, is such that no meaningful comparison could be made between any two records. It would be possible, for example, to select a VER for red and green stimuli which were completely different; on the other hand, records can be found which show virtually no difference between red and green. Similar results are found in the VER's of all subjects.

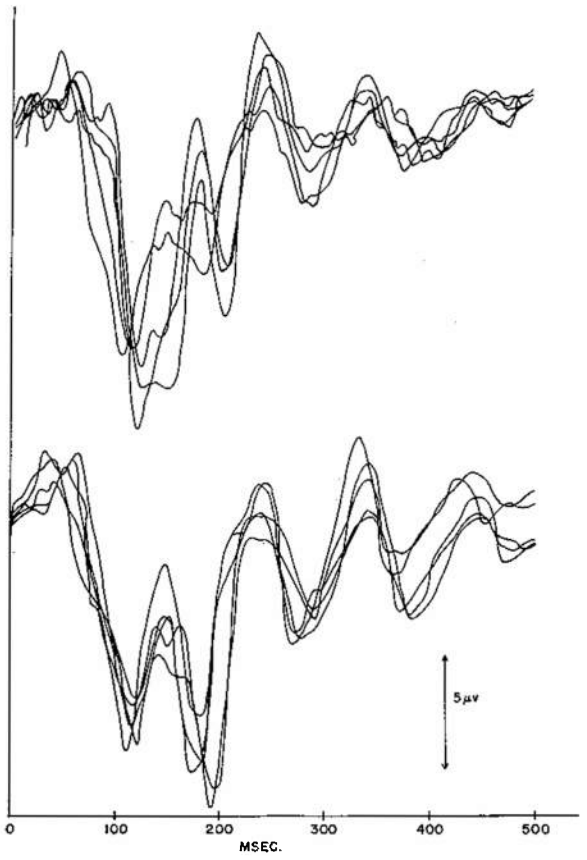

Fig. 3. Five VER's from one subject in response to a red field at the top and a green field at the bottom. Interval between first and last records was two months.

Nonetheless, a comparison of the group of VER's from red stimuli with those evoked by green reveal some general differences, notably that the red curves are higher than the green in the regions from 80 to 110 msec and from 160 to 190 msec.

***Throughout the paper we will use the convention of positive up, negative down. Since the recording is bipolar, there are no positive and negative poles in the absolute sense. Here, however, positive refers to greater positive activity at the position 7 cm above the inion than at 2 cm above; negative refers to the reverse.*

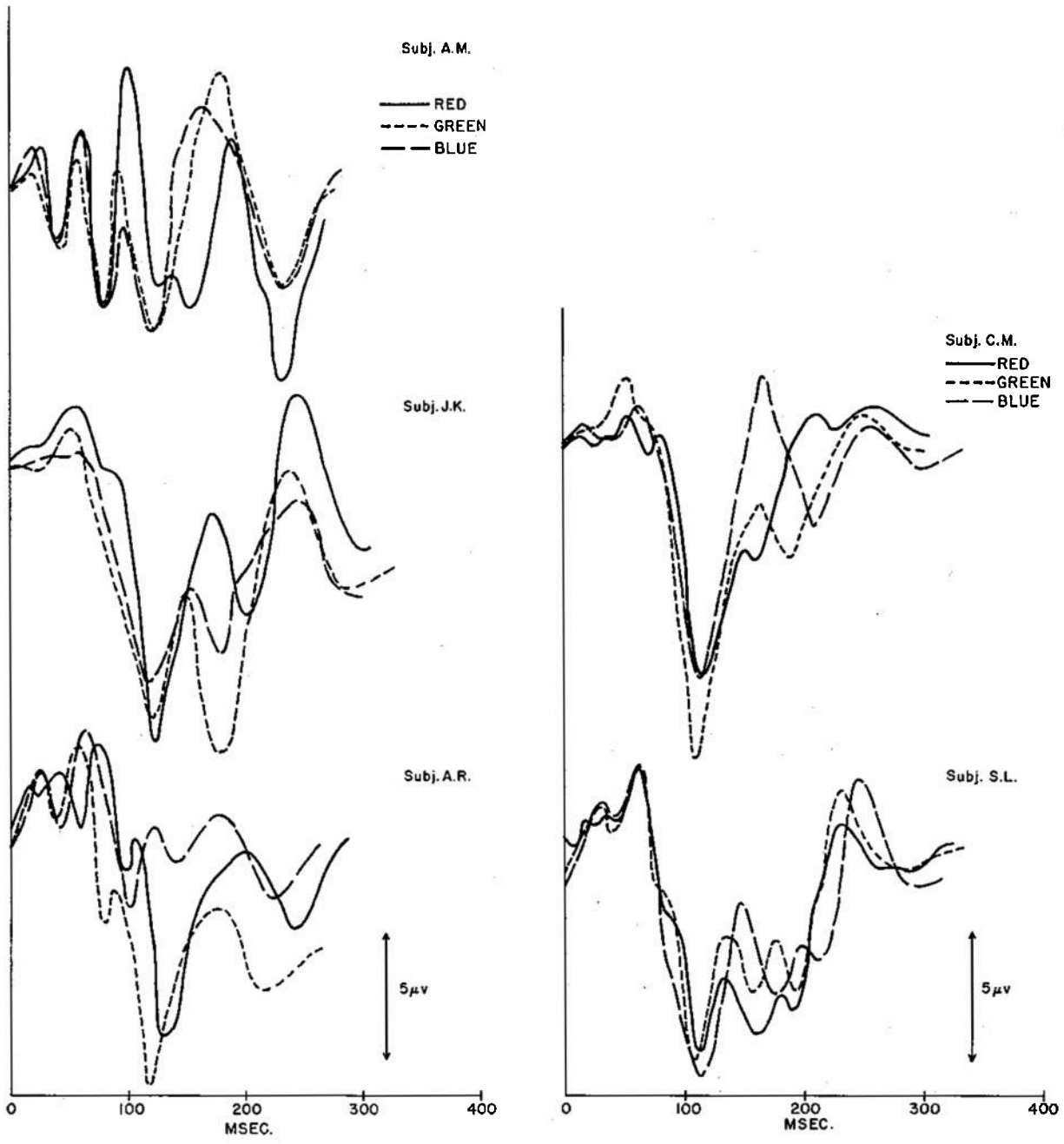

Fig. 4. Mean VER's for five subjects recorded from fields of red, green, and blue.

Figure 4 shows the mean curves for red, green, and blue fields for five subjects. The difference between red and green for JK, described above, is clearly seen in the average curve of Fig. 4a. The average data for all subjects show differences among colors. While the differences are not always the same from one subject to the next, the latency of the red positive component at 180 to 200 msec is greater than that of blue and green for all except the dichromatic subject, SL.

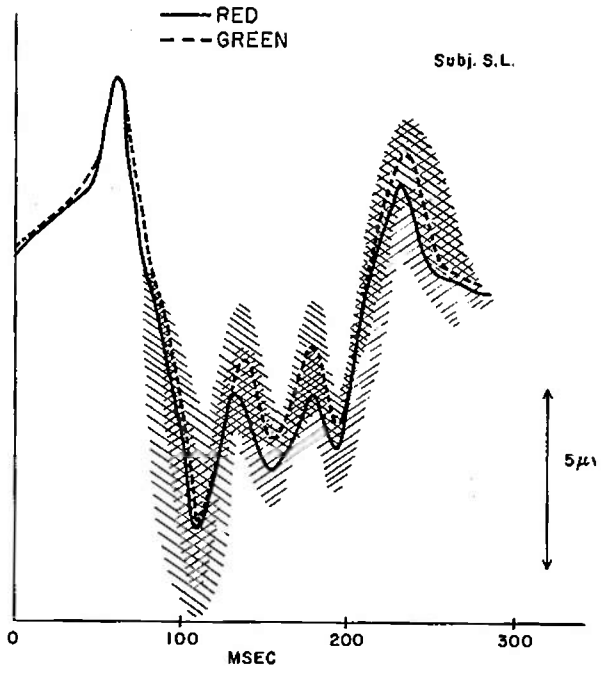

Fig. 5. Mean VER's and standard deviations for the deuteranopic subject, SL, for red and green targets. Each curve is the average of 10 different VER's.

A double factorial analysis of variance was performed on the latencies and amplitudes of the major components for each subject. Summary tables III and IV for each analysis are given in the Appendix. Significant differences among colors were found for both latency and amplitude for all subjects. Also, the interaction between component and color was significant for all subjects, except for the amplitude analysis for SL, indicating that there are larger differences among colors for some components than for others.

Inspection of the data for the deuteranopic subject (Fig. 4b) shows that the components of the VER's to red and green have the same latency, while those for blue differ. Therefore a more extensive analysis was performed for the red and green responses, for which ten curves were available on each color; the resultant average curves are in Fig. 5. The curves are the same shape, with no differences in latency; the differences in amplitude between curves are much smaller than the standard deviation of either curve; and analysis of variance showed no significant differences between colors for either latency or amplitude (Tables V and VI).

The significant color difference found in the previous analysis for SL was thus due to the blue response. This is in good agreement with psychophysical data; deuteranopes confuse many reds and greens but can distinguish them from blue. [16] In fact color confusions were determined for SL in a previous study; [17] these are replotted in a CIE chromaticity diagram in Fig. 6

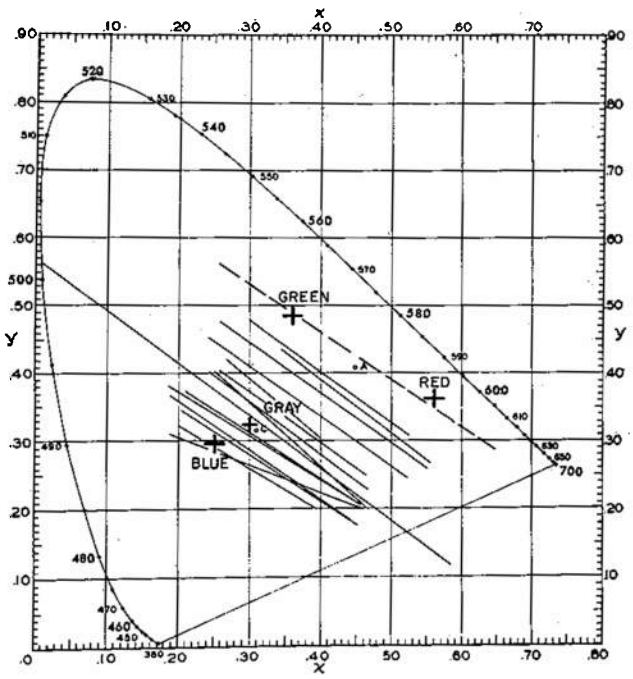

Fig. 6. CIE chromaticity diagram of the colored stimuli used in this experiment (+) and the color confusion lines of subject SL (see reference 17 for details).

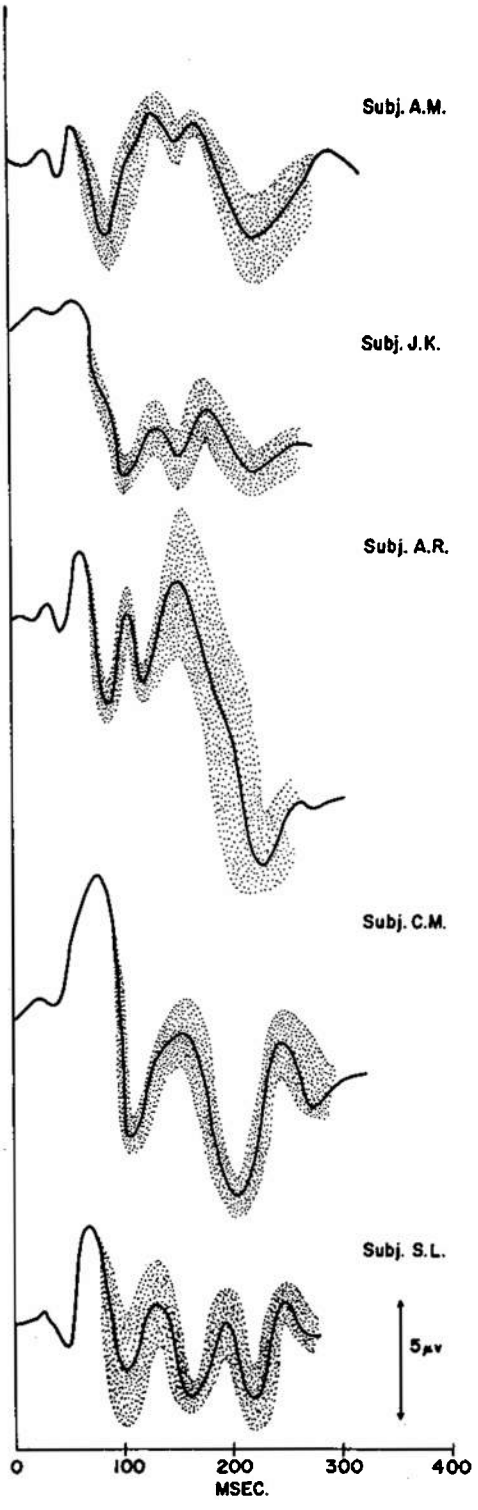

Fig. 7. Mean VER's and standard deviations for a striped field of gray and white for five subjects.

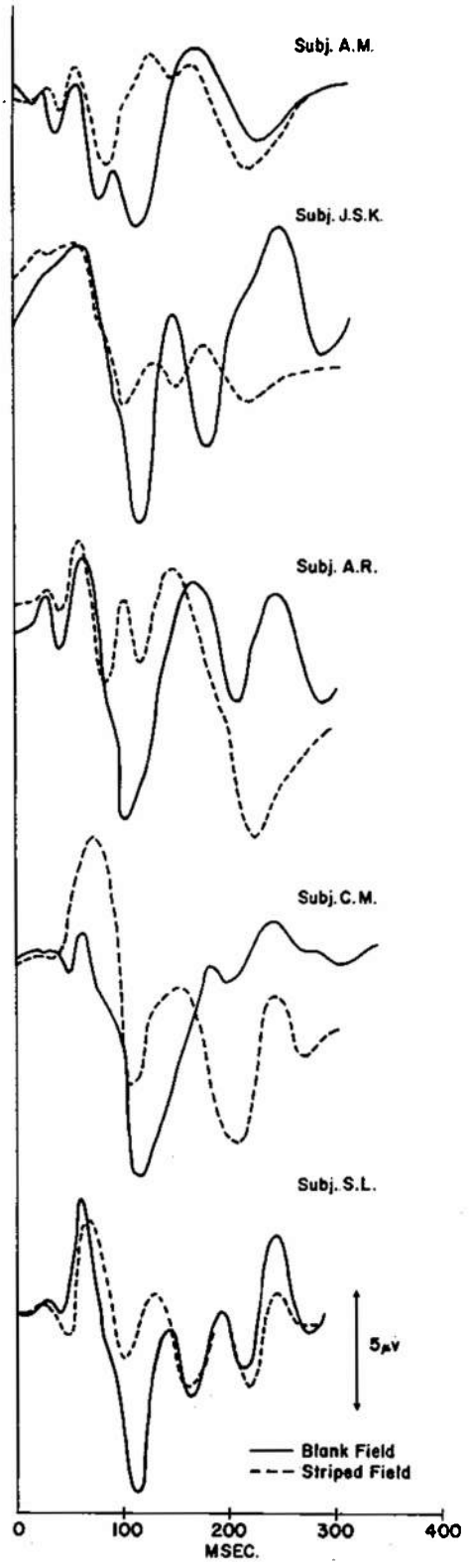

Fig. 8. Comparison of VER's to blank and striped fields.

together with the stimuli from this study. The red and green targets lie on a line nearly parallel with his confusion lines, indicating they have the same color appearance to him, while the blue is on the opposite side of his white point.

Striped Patterns of Color and White

A similar analysis for data obtained with striped patterns was performed. Figure 7 gives the average curves for five subjects for the gray and white striped pattern (Table VII). A comparison of these curves with those obtained with a blank field of gray, in Fig. 2, is made for each subject in Fig. 8. The differences between curves for the blank field vs. striped field are so large that it is difficult to obtain comparable components in many cases; this means the analysis illustrated previously for differences among hues — a statistical assessment of component latencies and amplitudes — is relatively meaningless in this instance.

The Add/Sub Technique — Comparison of Responses to Striped and Blank Fields

However, it is possible to predict from the two curves what the resultant curve should be if evoked responses to one visual target were summed by the computer while an equal number to the other target were subsequently subtracted. For example, for subject AM, if responses to blanks were subtracted from those to stripes, there should be a peak of activity from 80 to 140 msec and a dip from 160 to 250; the remainder of the evoked response to the two patterns should cancel.

Figure 9 shows the result of this "add/sub" technique, for a full second of time; the predictions made from the individual curves to a blank and a striped field are completely verified.

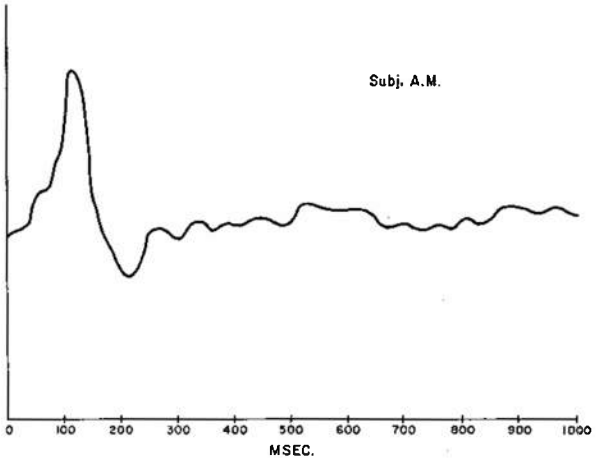

Fig. 9. VER for a full second obtained by subtracting 200 responses to a blank field of gray from 200 responses obtained for a striped field of gray.

†For simplicity of comparison, all of the curves in this section are presented with the addition of striped responses and the subtraction of those to a blank field. However, any order of presentation or of addition and subtraction may be used and, in the actual experiment, the responses to the blanks and stripes were counterbalanced for order of presentation.

Figure 10 gives samples of the "add/sub" records for the first 500 msec for each subject for the condition in which data for the blank field of gray were subtracted from the striped gray field. A careful comparison between individual data in Fig. 8 and Fig. 10 reveals some remarkable consistencies. First, the data among subjects are comparable to the extent that all have a prominent peak of activity between 100 and 130 msec and all have a sizeable dip somewhere between 200 and 250 msec. Furthermore, the bases of individual differences can be found in the original curves of Fig. 8. The amplitude differences between striped and blank field are largest for AR, a fact that is reflected in Fig. 10. The peak positive activity for JK at 180 msec shown in Fig. 10, is found in the original curves of Fig. 8, where a prominent dip at 180 msec is found in the blank field data for this subject only.

Comparable analyses can be performed by comparing VER's obtained from targets formed of colored stripes with those from blank fields of the same color. Examples for two subjects are given in Figs. 11-14. Figure 11 gives the VER's for the striped patterns for the two subjects; the waveforms are similar in shape for the different colors, but the amplitudes of components are significantly different for both subjects, as are either the latencies or the color by latency interaction. (See Tables VIII and IX.)

Overlays of the VER's from a striped and blank field of the same color are shown in Fig. 12 for both subjects, for

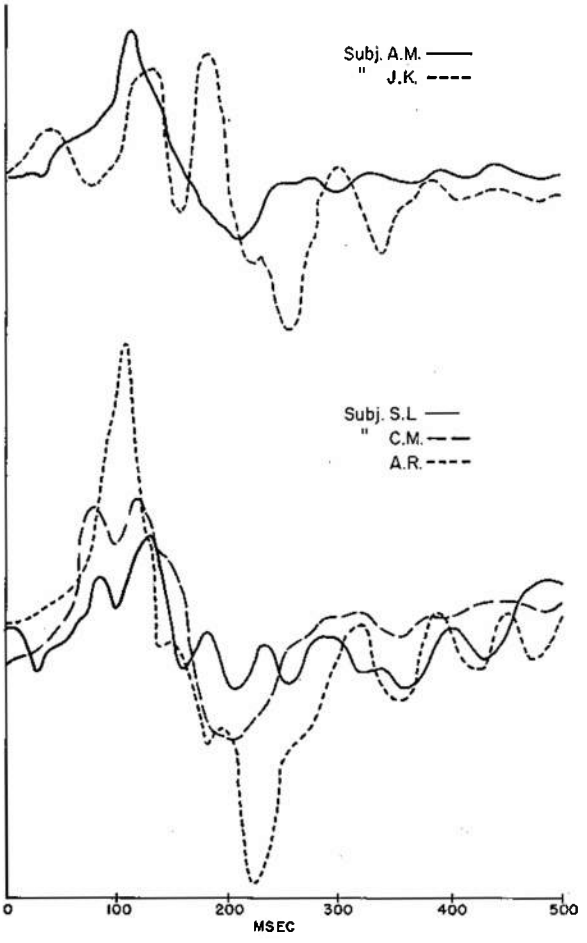

Fig. 10. Comparison of VER's of four subjects obtained by adding 200 responses to the gray and white striped pattern and subtracting 200 to the blank field of gray.

red, green, and blue. Figure 13 gives curves which result when VER's are amassed by adding and subtracting responses in the same experimental session for JK. The full one-second interval is shown illustrating the point that activity does cancel after the first few hundred milliseconds.

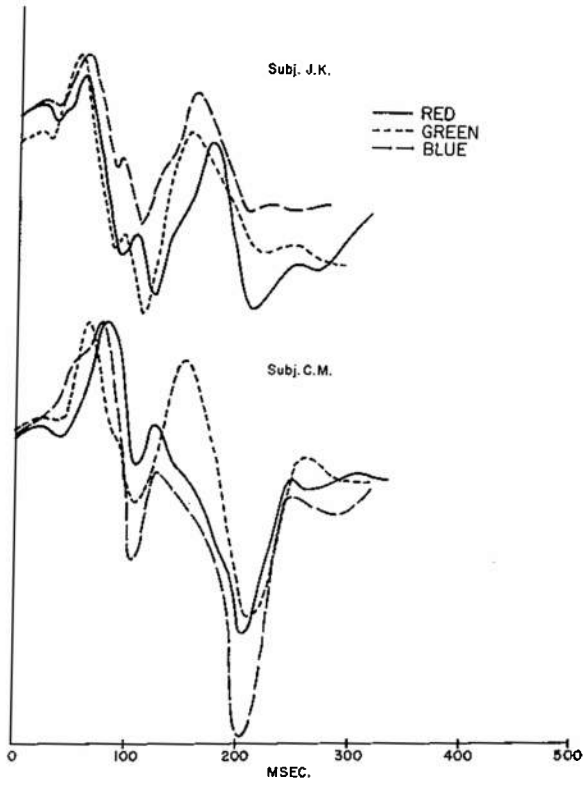

Fig. 11. Mean VER's from patterns formed of red, green, or blue and white stripes for two subjects.

Figure 14 gives the first 500 msec for CM, using the Add/Sub technique. The agreement between predictions from Fig. 12 and the empirical curves in Fig. 14 is excellent. Not only are the overall shapes as predicted but smaller details are in agreement as well. Note in Fig. 12 for example that the crossover from predominantly more positive to more negative activity, for the striped pattern, occurs first for blue, at about 150 msec, next for red, finally for green. These predictions are clearly evident in Fig. 14.

While the technique of adding and subtracting responses to different patterns is highly effective in revealing the difference between blank fields and stripes, it is not as successful for all features. For example, one can attempt to extract hue components by adding responses to a red field and subtracting the same number to a field of gray. Similarly, the same hue component should be extractable from Add/Sub responses to red and gray striped patterns.

Figures 15 and 16 show, for the same two subjects, the resulting VER's obtained with both patterned and blank fields when responses to gray stimuli are subtracted from responses to stimuli of red, green, or blue. In general the differences attributable to hue are very small but some major features are predictable from the individual VER's. (Compare, for example, Fig. 2 with Fig. 4 and Fig. 7 with Fig. 11.) The hue features are greater and more reliably obtained for long wavelength stimuli than for short; there appears to be no difference between gray and blue for these two subjects.

DISCUSSION

The visual evoked responses obtained with a slow rate of stimulus presentation in this investigation show the large amount of variability found by others. For the same subject and the same conditions, differences for the various components of the VER on different days may reach 10 msec in latency and 3 μv in amplitude. Since differences due to stimulus parameters are often of

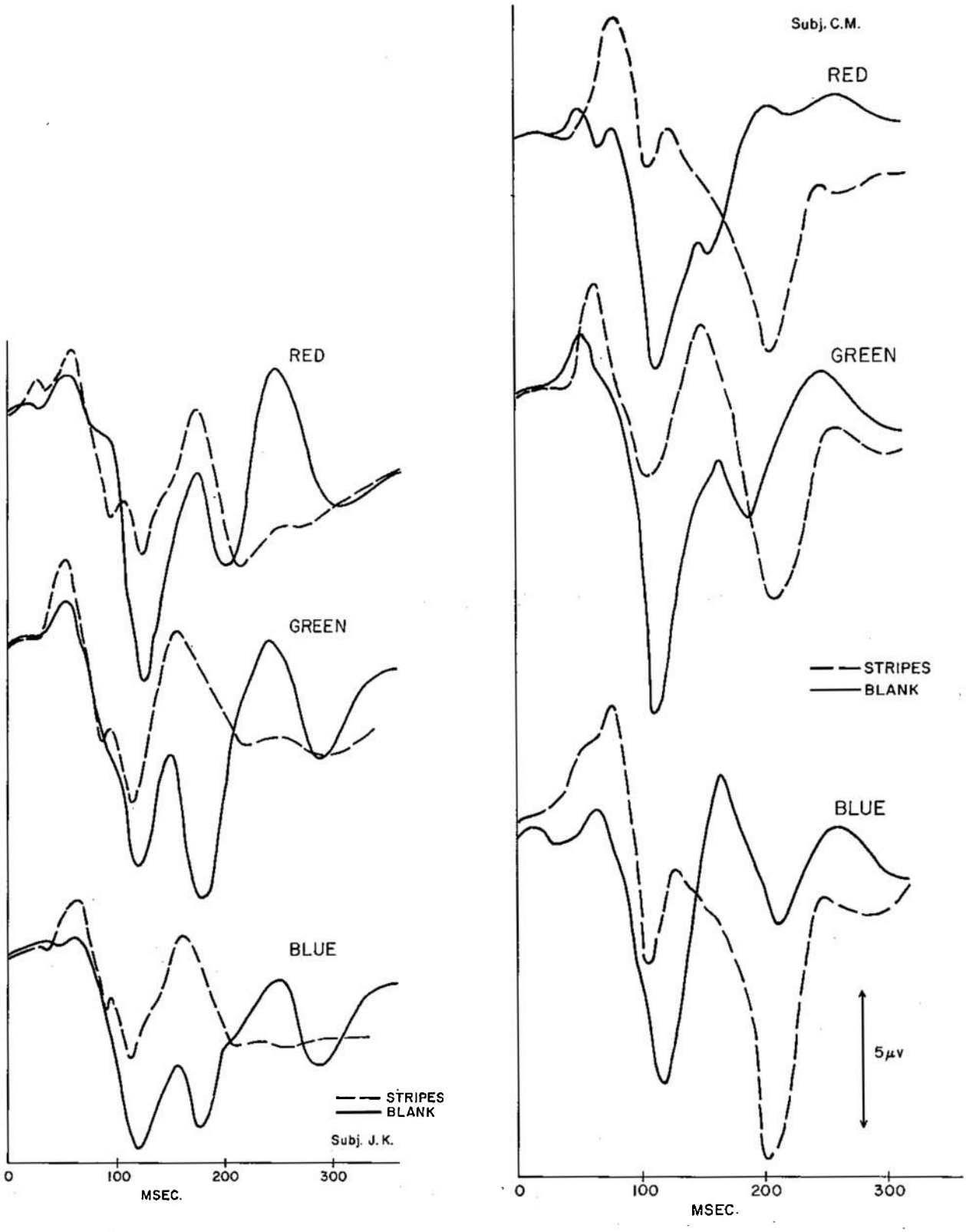

Fig. 12. Comparison of mean VER's from striped and blank fields of red, green, and blue for two subjects.

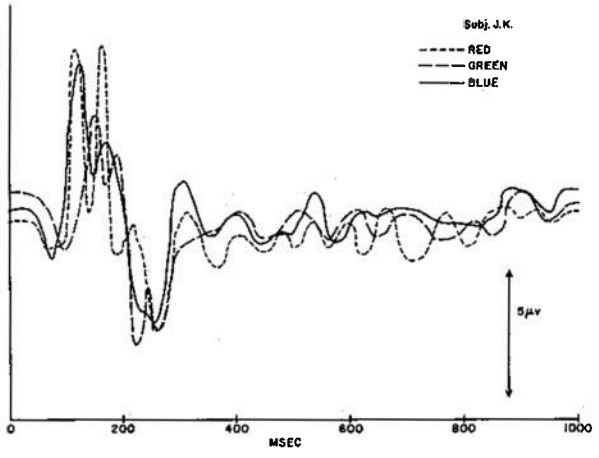

Fig. 13. VER's amassed by adding 200 responses to a striped pattern and subtracting 200 to a blank field of the same color. Subject JK.

the same order of magnitude, obviously repeated measurements and some type of statistical analysis are required to determine whether or not a given experimental condition is indeed affecting components of the VER. A further complication is introduced by the fact that differences among individuals are large and sometimes it is impossible to find even the same components in the records for different subjects.

Two techniques are presented in this paper which are helpful in overcoming these problems. First is the determination of an average VER, based upon the latencies and amplitudes of the

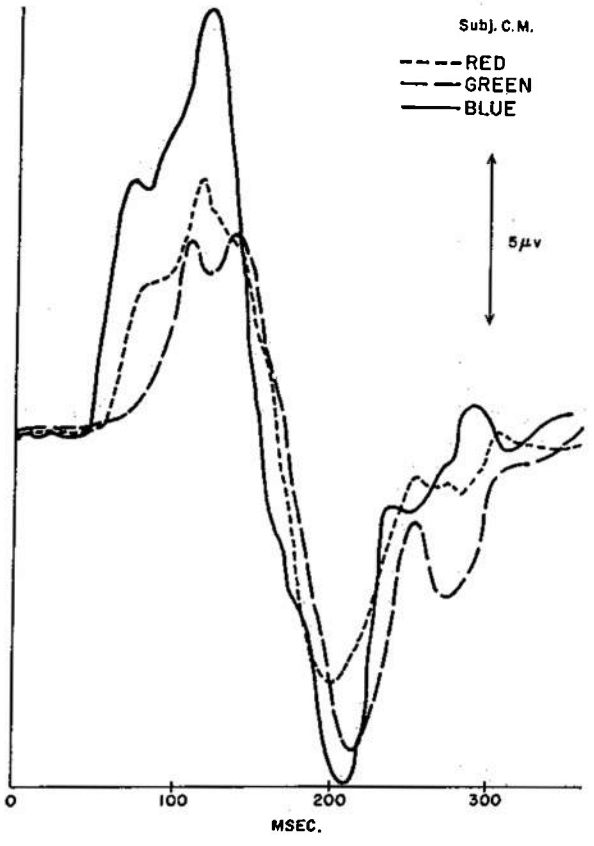

Fig. 14. VER's amassed by adding 200 responses to a striped pattern and subtracting 200 to a blank field of the same color. Subject CM.

various components of the waveform; at least 5 or 6 summated VER's are required for such an analysis. Means and standard deviations are calculated and any statistical analysis based on the

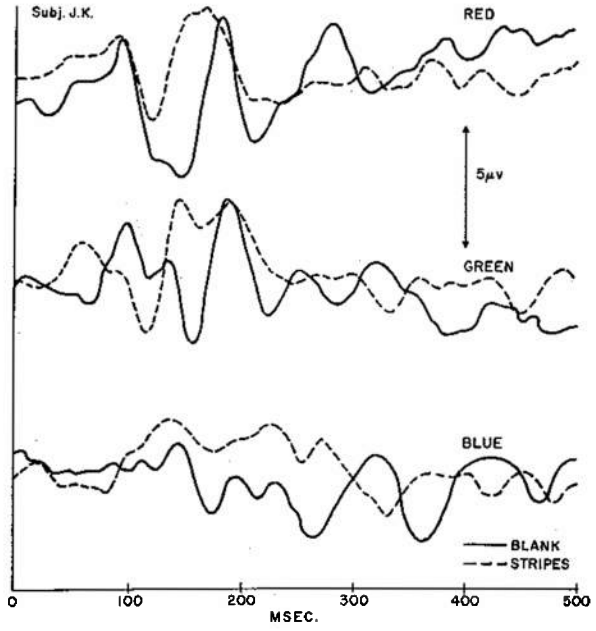

Fig. 15. VER's amassed by adding 200 responses to a colored target (red, green, or blue) and subtracting 200 responses from a gray target. Add/Sub curves for blank fields ; for striped fields - - - -. Subject JK.

normal distribution can then be employed, both for differences in amplitude and in latency. Thus t tests or analysis of variance, for example, will evaluate the significance of differences among experimental conditions.

In this analysis each subject serves as his own control. A sizeable number of records can be obtained under stand-

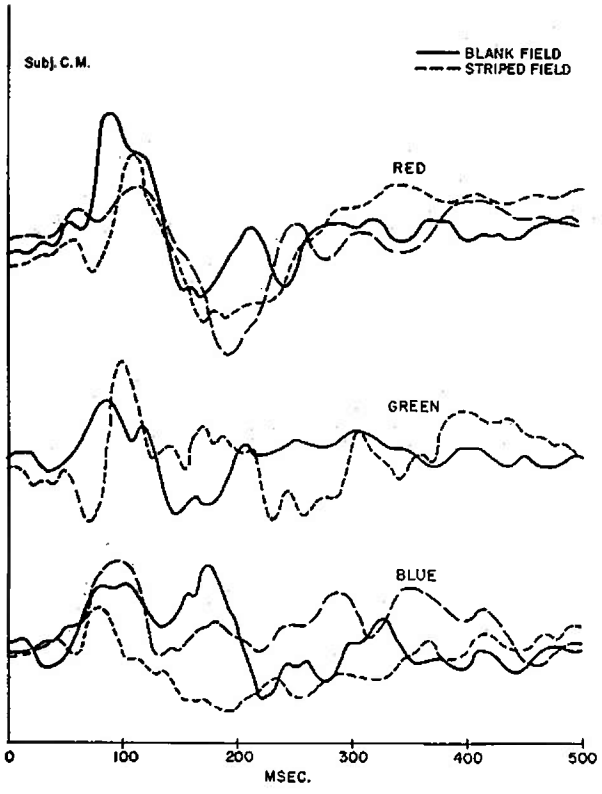

Fig. 16. VER's amassed by adding 200 responses to a colored target (red, green, or blue) and subtracting 200 responses from a gray target. Add/Sub curves for blank fields ; for striped fields - - - -. Subject CM.

ard, control conditions; the mean curve can be calculated and plotted together with its standard deviation—as in Fig. 2—

to provide a picture of the normal range of variability for a given subject under given conditions. If the experimental conditions are unusual and preclude obtaining a number of VER's under the same conditions, then a single record can be compared with this average to see if it lies within or outside the normal range of variation. Thus, for example, we used the average curve obtained under control conditions to compare with VER's obtained from divers in a chamber dive to 250 ft. [18]

The second technique evaluated in this paper is the method of adding and subtracting responses that has been proposed by Carroll White. This is an extremely useful and informative method in certain circumstances. If two conditions yield VER's that differ substantially, the use of the statistical technique outlined above may be difficult because the same components cannot be found in the records. In such a case however, a direct comparison of two VER's will allow a simple prediction of the amplitude and latency of the differences between the two records. Empirical tests of the predictions, by adding responses to one stimulus and subtracting those to the other, can be made. Thus VER's obtained with striped stimuli were very different from those obtained with blank fields of the same size. The records obtained by adding responses to striped patterns and subsequently subtracting responses to blank fields or vice versa were in excellent agreement with predictions made from a direct comparison of individual records for striped and blank fields. This is in complete agreement with White's analysis, and, in fact, the resulting elements extracted for patterned stimuli—additional positive activity around 100 msec and negative around 200 msec—are similar to White's. In addition we have shown that it is possible to extract the same elements from patterns and blank fields formed of gray, red, green, or blue colors.

Another advantage accrues to this technique: comparison can be made among subjects even though their individual VER's are not at all similar. Thus the five subjects in this study did not show the same components in their VER's, but similar elements for patterned stimuli were revealed by the add/sub technique.

On the other hand, an attempt to extract elements related to the perception of hue, by adding responses for a colored stimulus and subtracting those for a gray field, were not nearly so successful. There are at least two possible reasons for this failure. First, the VER's to stimuli which differ only in hue are very similar; the same components, with approximately the same amplitude and latency, are found for all hues. Statistical analysis was required to test the significance of the differences. Thus it is certainly possible that small changes in the evoked response over time could mask the element being extracted.

On the other hand, there is another, much more basic possibility: the elements that can be extracted by the add/sub technique reflect an underlying physiological mechanism sensitive to the stimulus property being assessed. In this case, it is possible that the large population of neurons that respond to

pattern are relatively important in the development of the cortical response, but that those responding to, say, red contribute less to the VER. As such, the red response is not easily extractable by this technique.

The emphasis in this paper has been upon methodology for use with the VER, since our primary interest is in using it as a tool in the study of Naval problems. In this connection, we have settled on a statistical technique for testing subtle differences in evoked response and an empirical methodology for dealing with sizeable differences. A third technique, that of employing a rapid rate of stimulation, is the subject of another report. In the course of these investigations, we have found an element in the VER strongly stimulated by patterned stimuli and small differences among VER's attributable to hue. The latter are in excellent agreement with psychophysical data on the color response of normal and dichromatic subjects.

SUMMARY

Techniques have been evolved to assess the significance of differences among visual evoked responses. One of these, a determination of mean VER, is effective in evaluating the statistical significance of subtle differences among evoked responses. Thus it has been possible to show differences in the VER's of color-normal subjects to stimuli of red, green, and blue.

The second technique is to isolate underlying processes in the VER by summating responses to one stimulus and subtracting the same number of responses to another. This method is particularly effective for making comparisons among subjects, and for analyzing the contribution of patterned stimuli to the VER.

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Table II. Latencies of Components and Differences in Amplitude Between Components of VER's to Blank Field of Gray.

Components	Latency (msec)		Differences in Amplitude (cm)	
	Mean	σ	Mean	σ
Subj: AM				
A	59.6	1.6		
B	83.0	4.0	5.7	1.4
C	95.0	3.2	1.2	0.8
D	114.0	3.7	2.8	1.4
E	166.0	3.7	8.7	1.7
F	230.0	6.3	4.8	0.6
Subj: JK				
A	61.0	2.0		
B	120.0	3.2	13.3	0.9
C	152.0	2.4	10.0	2.7
D	179.0	3.7	6.2	1.7
E	248.0	4.0	10.3	1.5
Subj: CM				
A	60.0	3.2		
B	112.0	2.4	11.5	1.9
C	180.0	3.2	10.1	1.8
D	195.0	11.8	0.8	0.1
E	237.0	2.4	3.0	2.2
Subj: AR				
A	29.0	5.8		
B	43.0	4.0	2.6	0.9
C	63.0	4.0	4.3	1.1
D	102.0	6.8	12.6	2.3
E	168.0	9.8	11.6	2.6
F	208.0	4.0	5.5	1.7
G	244.0	8.0	5.2	1.0
Subj: SL				
A	61.2	3.4		
B	114.8	5.2	13.9	2.1
C	143.6	3.9	7.5	0.9
D	163.2	10.3	3.3	1.5
E	193.2	10.1	4.1	0.6
F	212.4	9.1	2.9	2.2
G	242.0	2.8	6.5	3.1

Table III. Analysis of Variance of the Latencies of Components of VER's from Blank Fields of Red, Green, and Blue.

	Sum of Squares	df	MS	F
Subj: AM N = 6 VER's per color				
Components	400,270.61	5	80,054.12	2,101.15 *
Colors	2,597.69	2	1,298.84	34.09 *
Comp. X Color Interaction	4,599.46	10	459.94	12.07 *
Within	3,429.24	90	38.10	
Subj: JK N = 6				
Components	340,576.11	4	85,144.02	1,062.83 *
Colors	1,842.23	2	921.11	11.49 *
Comp. X Color Interaction	1,885.47	8	235.68	2.94 *
Within	6,008.42	75	80.11	
Subj: CM N = 6				
Components	335,476.96	4	83,869.24	415.59 *
Colors	6,785.42	2	3,392.71	16.81 *
Comp. X Color Interaction	7,867.91	8	983.49	4.87 *
Within	15,135.67	75	201.81	
Subj: AR N = 5				
Components	468,267.73	7	66,895.39	542.84 *
Colors	7,618.20	2	3,809.10	30.91 *
Comp. X Color Interaction	3,157.27	14	225.51	1.82 **
Within	11,830.80	96	123.23	
Subj: SL N = 5				
Components	296,405.71	6	49,400.95	1,071.13 *
Colors	2,888.59	2	1,444.29	31.31 *
Comp. X Color Interaction	1,087.15	12	90.59	1.96 **
Within	3,874.40	84	46.12	

* Significant at .01 level
** Significant at .05 level

Table VI. Analysis of Variance of Latency and Amplitude of Components of VER's from Red and Green Fields for Deuteranopic Subject, SL.

	Sum of Squares	df	MS	F
Latency N = 10 VER's per color				
Components	377,425.70	6	62,904.28	1,181.74 *
Colors	13.83	1	13.83	.26
Comp. X Color Interaction	85.47	6	14.24	.27
Within	6,707.00	126	53.23	
Amplitude				
Components	1,945.21	5	389.04	115.48 *
Colors	5.29	1	5.29	1.57
Comp. X Color Interaction	4.08	6	0.68	0.20
Within	363.87	108	3.37	

* Significant at the .01 level.

Table VII. Latencies of Components and Differences in Amplitude Between Components of VER's to Striped Field of Gray and White.

Component	Latency (msec)		Difference in Amplitude (cm)	
	Mean	σ	Mean	σ
Subj: AM				
A	57.8	3.4		
B	85.5	3.6	5.1	1.5
C	127.3	2.7	5.6	1.1
D	149.7	10.3	1.4	1.0
E	165.7	6.1	0.7	0.6
F	217.8	10.2	5.2	1.9
Subj: JK				
A	58.3	3.0		
B	100.3	4.2	8.0	0.7
C	128.3	8.2	2.3	1.3
D	150.5	15.9	1.7	1.2
E	173.2	17.2	2.4	1.4
F	214.7	8.8	2.8	1.0
Subj: CM				
A	75.4	4.1		
B	106.4	3.4	12.2	0.7
C	153.2	7.5	4.8	1.6
D	204.8	6.4	7.7	0.9
E	244.2	3.1	7.2	1.5
Subj: AR				
A	43.0	3.0		
B	59.8	2.7	3.7	1.0
C	85.2	6.0	6.8	1.0
D	101.6	10.2	3.9	1.2
E	114.8	13.4	3.2	0.7
F	150.6	8.4	4.7	3.3
G	222.4	7.7	13.1	2.5
Subj: SL				
A	67.4	6.6		
B	101.2	5.9	6.7	2.5
C	128.0	5.5	3.2	1.9
D	159.4	5.0	4.4	0.7
E	190.8	7.1	3.5	1.5
F	216.8	8.4	3.8	1.5
G	242.8	6.5	4.5	0.8

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13. ABSTRACT

The emphasis in this report is upon methodology for use in evaluating the visual evoked response (VER), since our primary interest is in using it as a tool in the study of Naval problems. In order to employ the VER to full advantage, techniques have to be evolved to assess the significance of differences among evoked responses; two such methods are assessed in this paper. One of these, a determination of a mean VER, is effective in evaluating the statistical significance of subtle differences among evoked responses. The second technique is designed to isolate differences in underlying processes in the VER by summating responses to one stimulus and subtracting the same number of responses to another. In the course of these investigations, we have found an element in the VER strongly responsive to patterned stimuli and small differences among VER's attributable to hue. The latter are in excellent agreement with psychophysical data on the color response of normal and color defective subjects.

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